

# REPORT DOCUMENTATION PAGE

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<p style="text-align: center;">Identification</p> <p>This document is a report of work done under Air Force Office of Scientific Research (AFOSR) award number P49620-02-1-0200 entitled "Precision Structural Mechanics Instrumentation System" under the Defense University Research Instrumentation Program (DURIP).</p> <p style="text-align: center;">Document Summary</p> <p>This document summarizes the instrumentation and data acquisition equipment acquired via this grant. The central signal conditioning and digitizing subsystem equipment was acquired as proposed with only minor upgrade exceptions. A newly available upgrade of the interferometry subsystem was accommodated within the budget by reducing the quantity of accelerometers which were acquired. The document also references both Air Force and NASA funded research impacted by this instrumentation system.</p> <p style="text-align: center;">Document Organization</p> <p>This report is organized as follows. Section 2 describes the acquired instruments and data acquisition equipment which was integrated as the precision structural mechanics instrumentation system. Section 3 references research projects which have already been affected by this instrumentation system. Section 4 summarizes the outcome of the instrumentation acquisition enabled by this grant.</p>			
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# ***Precision Structural Mechanics Instrumentation System: Final Performance Report***

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## **1.0 Scope**

### **1.1 Identification**

This document is a report of work done under Air Force Office of Scientific Research (AFOSR) award number F49620-02-1-0200 entitled "Precision Structural Mechanics Instrumentation System" under the Defense University Research Instrumentation Program (DURIP).

### **1.2 Document Summary**

This document summarizes the instrumentation and data acquisition equipment acquired via this grant. The central signal conditioning and digitizing subsystem equipment was acquired as proposed with only minor upgrade exceptions. A newly available upgrade of the interferometry subsystem was accommodated within the budget by reducing the quantity of accelerometers which were acquired. The document also references both Air Force and NASA funded research impacted by this instrumentation system.

### **1.3 Document Organization**

This report is organized as follows. Section 2 describes the acquired instruments and data acquisition equipment which was integrated as the precision structural mechanics instrumentation system. Section 3 references research projects which have already been affected by this instrumentation system. Section 4 summarizes the outcome of the instrumentation acquisition enabled by this grant.

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## 2.0 Acquired Equipment

### 2.1 Signal Conditioning/Digitizing Subsystem

The National Instruments supplied signal conditioning and digitizing subsystem which was acquired is shown in Figure 2-1. The elements of this system are listed in Table 3-1. The primary elements of this system are combined dynamic signal conditioning/digitizing cards (NI 4472s) with 24-bit resolution. These cards alone have provided up to three orders of magnitude in resolution improvement over the previous digitizers available in the laboratory.

In addition, the PXI-based system provides significantly improved flexibility in synchronizing large numbers of sensors. Precise synchronization of experimental input and output measurements is critical to the rate and history dependent mechanics typical of the systems being studied. Prior inconsistencies in this synchronization greatly limited the quality of subsequent state map analyses.

Figure 2-1 National Instruments Signal Conditioning/Digitizing and Zygo ZMI 4000 Interferometry Subsystems as integrated in CU's Structural Dynamics and Control Laboratory

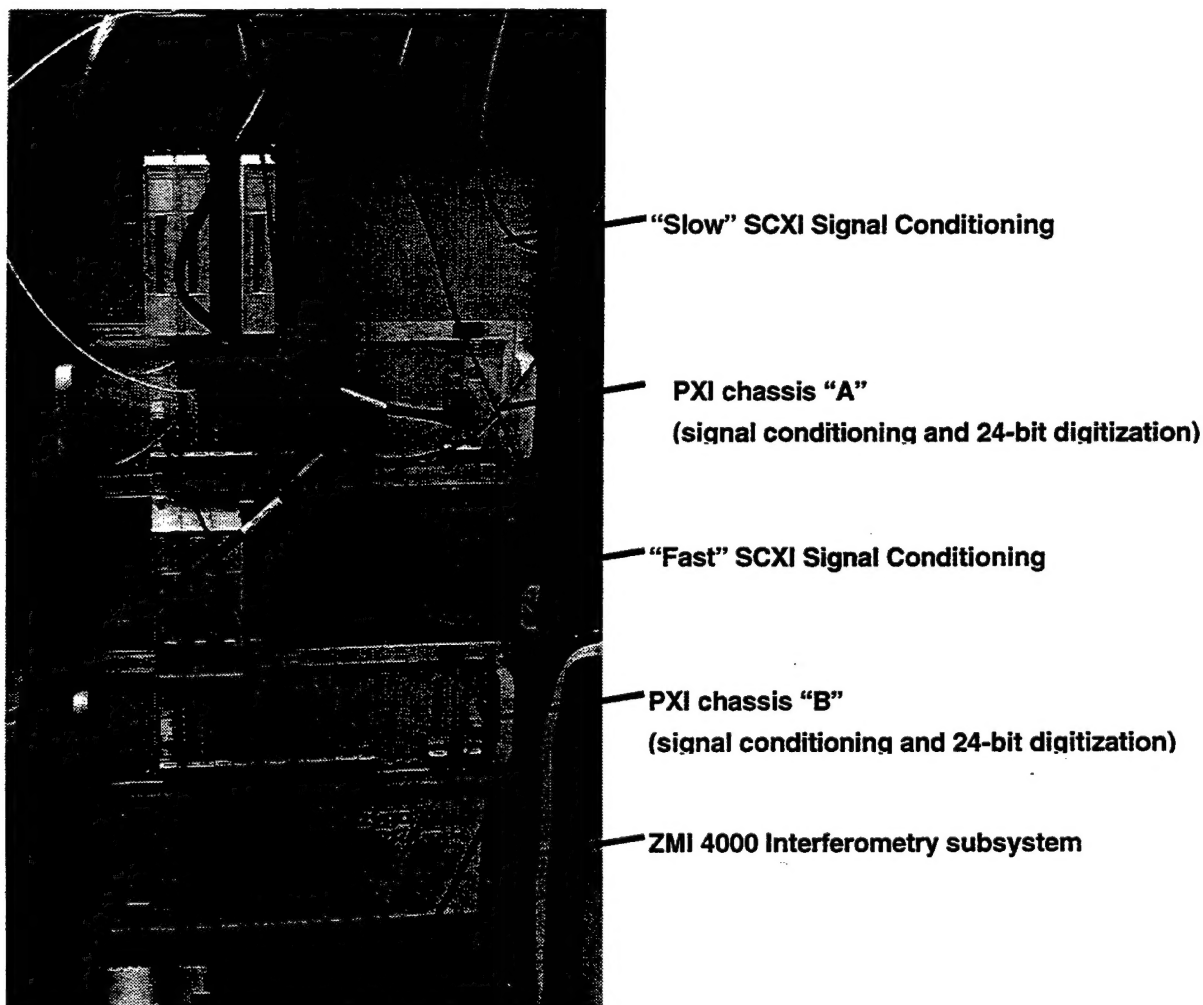


Table 2-1 Signal Conditioning and Digitization Subsystem Components

Model (Function)	Quantity
NI 4472 (8-channel ICP signal conditioning)	16
SCXI-1520 (Load cells)	2
SCXI-1314 (Load cells)	2
SCXI-1122 (RTDs)	2
SCXI-1322 (RTDs)	2
SCXI-1161 (Relays)	1
NI 6713 (Waveform generator)	1
SH68-68EP (Waveform generator)	1
TBX-68 (Waveform generator)	1
NI 6534 (Data communication)	1
TBX-68 (Data communication)	1
VME-PXI8015 (Interferometer)	1
PXI-GPIB (Communications)	1
NI 1408 (Frame grabber)	1
A2514-1 (Frame grabber)	1
SCXI-1125 (IC temperature)	1
SCXI-1313 (IC temperature)	1
SCXI-1520 (Foil strain gages)	1
SCXI-1314 (Foil strain gages)	1
NI 6052E (Multifunction DAQ)	1
SH-68-68EP (Multifunction DAQ)	1
TBX-68 (Multifunction DAQ)	1
PXI-1006 (18-slot PXI chassis)	2
SCXI-1001 (5-slot SCXI chassis)	1
PXI-6608 (Counter/timer)	1
TB-2715 (Counter/timer)	1
PXI-PCI8335 (PXI to PC connection)	1

Along with the interferometry and accelerometer subsystems described below, this subsystem permits simple integration of a variety of other sensors which were already on hand. These include piezoelectric and foil-based strain gages and force transducers as well as RTD temperature sensors. Existing ambient temperature, pressure, and humidity sensors are also easily integrated. Finally, the

PXI system includes a frame-grabber component for use with the videometry systems developed and used by SDCL.

## **2.2 Interferometry Subsystem**

The ZMI 4000 interferometry subsystem acquired from Zygo Corp is also shown in Figure 2-1. This system consisted of a custom VME chassis from Pentair Corp. housing two ZMI 4004 4-channel measurement boards. The upgrade to the 4000 class boards vs. the proposed 2000 series system became available between the proposal and procurement time frames. This system provided a full order of magnitude improvement in interferometry resolution in the laboratory.

This subsystem has addressed a number of SDCL measurement needs. Primary amongst these is its easy integration with the National Instruments PXI system. Zygo Corp.'s dual axis VME measurement boards can be directly integrated with the system described above. In addition, LabVIEW software drivers are available from Zygo Corp. for this form of integration.

The ZMI 4000 interferometry subsystem has also extended the useful life of an existing \$25,000 investment in interferometry optics. The laser head for the prior system is beyond its predicted lifetime and the ZMI 7702 laser head which was acquired will provide a 50,000 hr life expectancy.

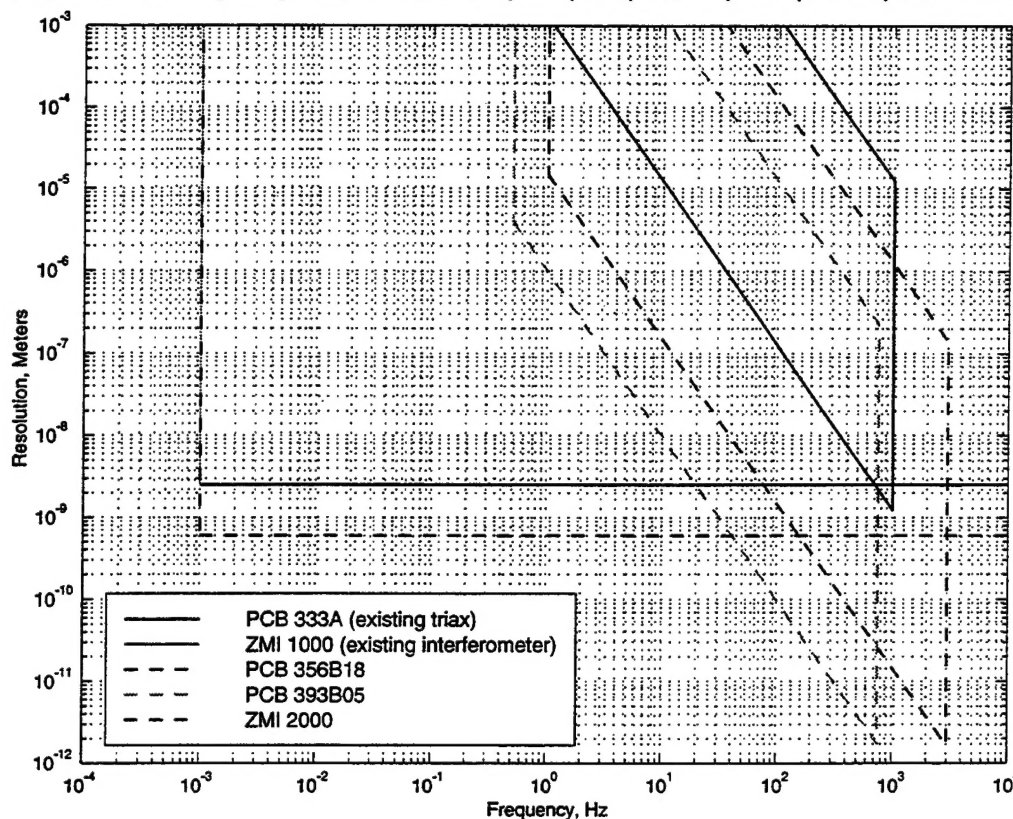
## **2.3 Accelerometers**

Cost increases in the interferometry system were accommodated in the proposed budget by reducing the number of accelerometers acquired from PCB. The number of 356B18 triaxial accelerometers was reduced from 30 to 22 and only 12 of the proposed 36 393B05 sensors were purchased. Future research program budgets will be able to accommodate any additional accelerometer requirements as needed.

The 356B18 triaxial and 393B05 single axis ICP accelerometers provide a flexible dynamic response sensing capability key to system-level structural dynamics research. While interferometry provides unmatched DC displacement resolution, accelerometers remain the most feasible method for observing the large number of degrees of freedom of complex structural systems.

Piezo-based sensing has kept pace with the remainder of the microelectronics community over the last decade. As a result, these sensors offer 10-100 fold improvement in sensitivity along with a 50% reduction in mass over the previously employed sensors. A comparison of the available resolution of both the prior and acquired interferometry and accelerometer instruments as a function of frequency is illustrated Figure 2-2. Improved resolution is indicated by the lower performance boundaries for the acquired accelerometers and interferometer system. Levels of measurement enhancement can be observed in the separation between the acquired and prior instrument resolutions.

Figure 2-2 Resolution vs. frequency boundaries for the prior (solid) and acquired (dashed) instruments



### 3.0 Related Research Programs

A number of Air Force and NASA research programs have already benefited from this instrumentation system acquisition. These include:

#### Post-buckled Mechanics Modeling of Elastically Deployable Composite Structures

AFRL Contract No. F29601-03-C-0134

Principal Investigator: Dr. Jason Hinkle, University of Colorado, (303)875-6152

#### Microscopic Plastic Behavior of Materials at Optical Scales of Deformation

AFRL Contract No. F29601-03-C-0134 (part 2)

Principal Investigator: Prof. Lee Peterson, University of Colorado, (303)492-1743

#### Technology Development for a Low-Cost Deployable Lidar Telescope

NASA HQ Project No. 258-70-117

Principal Investigator: Prof. Lee Peterson, University of Colorado, (303)492-1743

### **Development of a Cryogenic Steady Sliding Tribometer**

NASA JPL Proposal No. 0303.49.0411B

Principal Investigator: Dr. Jason Hinkle, University of Colorado, (303)875-6152

## **4.0 Conclusions**

As described above, the Precision Structural Mechanics Instrumentation System equipment was acquired essentially as proposed. A major update of the interferometry system became available following the proposal process which was accommodated by the budget by reducing the quantity of accelerometers which were purchased. This instrumentation system has already impacted a variety of Air Force and NASA research programs and will continue to be an enabling capability for the study of precision structural mechanics at the University of Colorado's Structural Dynamics and Control Laboratory for years to come.